

Assessment of microplastics occurrence and abundance in water and sediment from Lekki Lagoon, Ogun State, Nigeria

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Abstract

Microplastics (MPs) are ubiquitous sources of pollution in aquatic habitats, which have proven to be a source of concern to the world because of their consumption by aquatic animals and the risk of their introduction into the food web. This has been worsened by the absence of effective management of plastic wastes in Nigeria. This research calculated the abundance, distribution and properties of MPs in water, and sediment from Lekki Lagoon, and determined the types of polymers. The MPs were obtained through filtration and density separation, chemical digestion and were identified by inspection using a stereomicroscope. Polymer characterisation was done using ATR-FTIR spectroscopy. The SPSS (v26) was used to analyse data. The presence of MPs was observed in all matrices of the environment. Particles in water were 364 to 435 particles/L and sediment 459 to 611 particles/g. The prevailing shape was fragments and black MPs were the commonest colour. Some of the polymers recognized were PET, LDPE, PVC, PP. The results indicated the high possibility of aquatic organisms in the Lagoon being contaminated with microplastic present in the water and sediments. Public awareness drive and stringent plastic waste management rules are essential.

Keywords: Pollution, Aquatic organisms, Polymer identification, Microplastics.

Introduction

Microplastics (MPs) represent an increasing issue within world aquatic ecosystems with their extensive nature and their potential to penetrate food webs through trophic transfer (Narra *et al.*, 2022). These are generally less than 5 mm in size, either as the breakdown product of larger pieces of plastic waste material or as intentionally produced industrial material, used in cosmetics and cleaning supplies (Subaramaniam *et al.*, 2023). They are physically invasive in waterways, besides acting as vectors of toxic compounds in aquatic settings, which exposes them to compounded ecological and public health risks (Liu *et al.*, 2019a).

When consumed, MPs can occur in high concentrations in the gills, the gastrointestinal system, and even muscles of fish, causing physiological disruption, inflammation, and behaviour changes (Wright and Kelly, 2017). Such effects do not only pose an ecological concern but also leave doubt about the safety of eating fish (Dada and Bello, 2023) and using the water for domestic purposes.

Irrespective of growing international research interest in MP pollution, empirical evidence on the subject in freshwater systems in Nigeria is limited and inconsistent, especially in terms of how the relationship between the sediment, water, and biota occurs (Akinhanmi *et al.*, 2023). Anthropogenic activities, such as plastic waste management, fishing, and urbanisation, are largely contributing to the increased anthropogenic impact on the Lekki Lagoon. As these activities promote the infiltration of MPs into the aquatic system (Olarinmoye *et al.*, 2020; Oni *et al.*, 2020). However, there are only a few studies that critically evaluate the abundance, typology, and environmental consequences of MPs in this area (Idowu *et al.*, 2024; Amadi *et al.*, 2020). The existing literature gap does not reflect the depth of environmental burden by MPs in Nigerian lagoon systems. Also, the chemical make-up of MPs identified is rarely described which is required to ascertain the toxicity and environmental sustainability of the substance (Chen *et al.*, 2022b; Fang *et al.*, 2021). Such

limited information is an obstacle to the development of appropriate public health and environmental policies to reduce MP contamination in water bodies (Zhang *et al.*, 2021).

The study was aimed at critically comparing the spatial abundance, morphology, and polymer composition of MPs in water and sediment in the Lekki Lagoon. The characterisation of the polymers was carried out using ATR-FTIR to establish the nature and source of microplastics in the Lagoon. This study could be used as scientific contribution to waste management plans for the Lekki Lagoon.

Methodology

The study design was a cross-sectional study, to evaluate microplastic particles (MPs) in a multi-compartment ecosystem. Three sampling sites, Agbalegiyo, Wharf, and Ilamo, were selected based on spatial distribution and each site was about 1km apart, reflecting ecological and socio-economic gradients. Three replicate samples of water and sediment were collected from each of three different locations along the river, denoted as (S1, S2 and S3), with a gap of roughly 1 km between each location. At each sampling location, water samples were transferred into 2.5 L amber bottles that had been previously cleaned. The bottles were filled to the brim and moved against the flow of the river before being covered with a piece of aluminum foil and sealed. An ice bag was used to carry the water samples to the lab. Sediment samples were collected from the top 5 cm of the sediment using a stainless hand trowel. A 500 g sample of sediment was taken from the river sampling point. Sediment samples were transported to the lab in aluminium Ziplock foil bags and stored properly in an ice container before being analyzed in the lab.

1L of the water sample was filtered using a vacuum glass filtration apparatus with a 0.45 μ m nitrocellulose filter. The membrane filter was allowed to dry in a desiccator after which it was observed. Air-dried sediment samples in a fume cupboard were sieved with a 5 mm mesh and

separated on the basis of density in a saturated sodium chloride solution (density 1.2 g/cm³) and agitated using a glass rod and left to settle and were treated with 30% hydrogen peroxide to digest organic matter. This suspension was filtered and the membrane allowed to dry after which it was checked under a microscope (Thompson *et al.*, 2004).

Dried filter membranes were analyzed under 40 × 100 magnification using an Andonstsar AD246S-M stereomicroscope to check the morphology of the microbes by microscopic analysis. The visual identification recorded the data of the shape, size and colour of MP in all the samples. Standardisation of data was carried out and expressed as particles/L of water and particles/kg of sediment. ATR-FTIR spectroscopy on a sample of selected microplastic fragments was performed in order to characterise the types of polymers on an Agilent Cary 630 spectrometer. Polymer identity was determined based on resulting spectra to standard libraries such as Hummel and Aldrich (Idowu *et al.*, 2024).

The analysis of data was made with IBM's statistical package for social sciences (SPSS, version 26). The abundance of MPs was provided in the form of means and standard deviation and translated using a standardized unit per matrix. Statistically significant differences among sampling points were tested with one-way analysis of variance (ANOVA), and the mean variation across sampling points were separated using Duncan Multiple Range Test at ($p < 0.05$).

Results

Microplastic abundance in surface water displayed a clear spatial pattern, with 435 particles L⁻¹ recorded at Agbalegiyo, 378 particles L⁻¹ at Wharf,

and 364 particles L⁻¹ at Ilamo. Fragments dominated across sites, were fragment>fibre>film>foam>bead. Fragments constituted 36.86 %, 32.58 %, and 30.53 % of microplastics at Agbalegiyo, Wharf, and Ilamo respectively as showed in (Figure 1). Black particles were the dominant colour, contributing 32.12 %, 28.91 %, and 38.76 % of total counts at Agbalegiyo, Wharf, and Ilamo respectively. White and brown particles ranked second and third as showed in (Figure 2). Site-specific chi-square testing confirmed significant disparities in colour distributions ($P < 0.01$), evidencing spatial heterogeneity in source inputs.

Sediment microplastic counts exceeded water values, ranging from 458 particles kg⁻¹ at Ilamo to 611 particles kg⁻¹ at Wharf, with Agbalegiyo intermediate at 475 particles kg⁻¹ accounted for 38.68 % of microplastics in sediment at Wharf, while fibres dominated at Agbalegiyo (49.14 %). Across matrices, seventy-one per cent of recovered microplastics measured below 1000 µm, with a modal size class of 200–400 µm, underlining advanced fragmentation (Figure 3). Films and pellets were absent, indicating preferential retention of angular and fibrous particles over intact pellets. Colour distribution in sediments followed a black>white>brown>yellow hierarchy at Agbalegiyo and Wharf, whereas Ilamo presented black>white>brown>red>blue (Figure 4). Black particles constituted thirty-three per cent of sedimentary microplastics, suggesting substantial influx from tyre wear, soot, and degraded synthetic rubber, while yellow and blue particles together accounted for less than five per cent of counts.

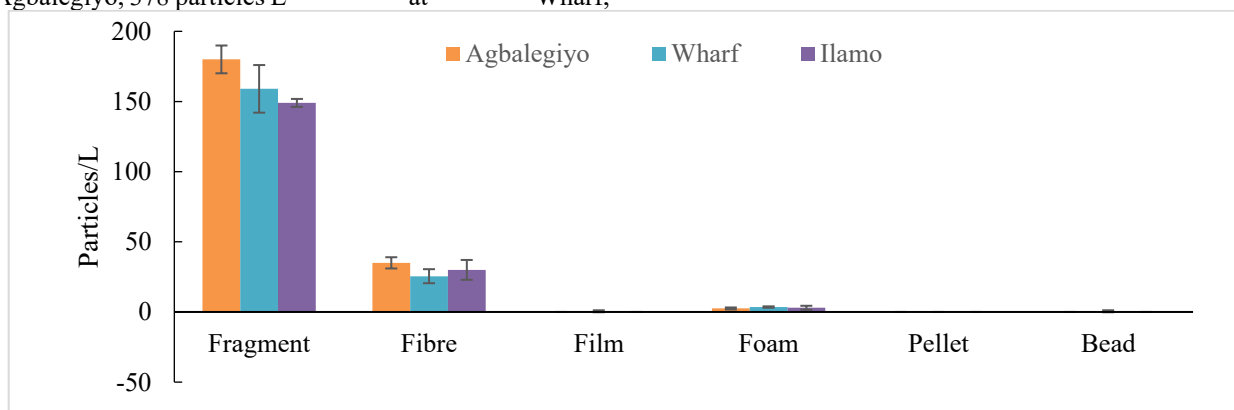


Figure 1: Distribution of microplastics shapes in water.

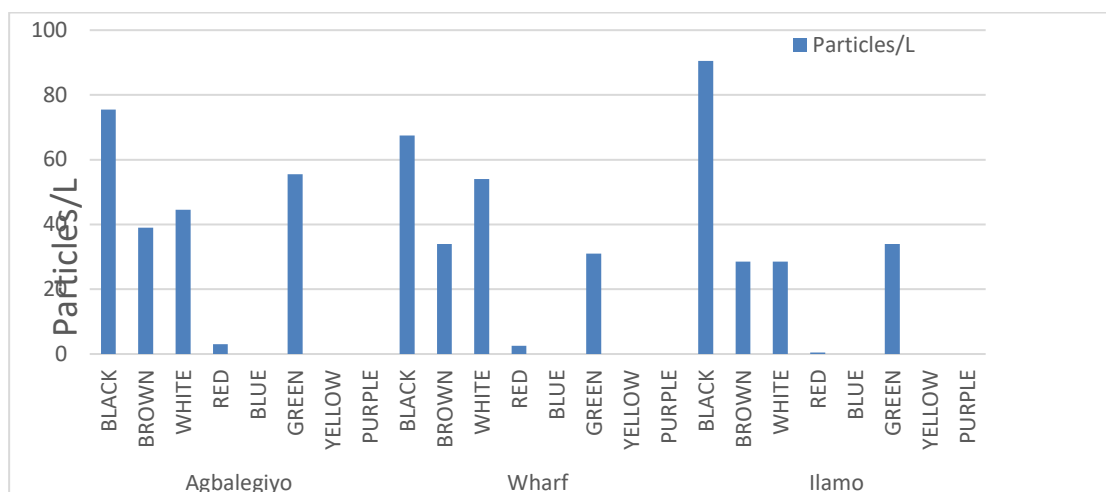


Figure 2: Distribution of microplastics colour in water

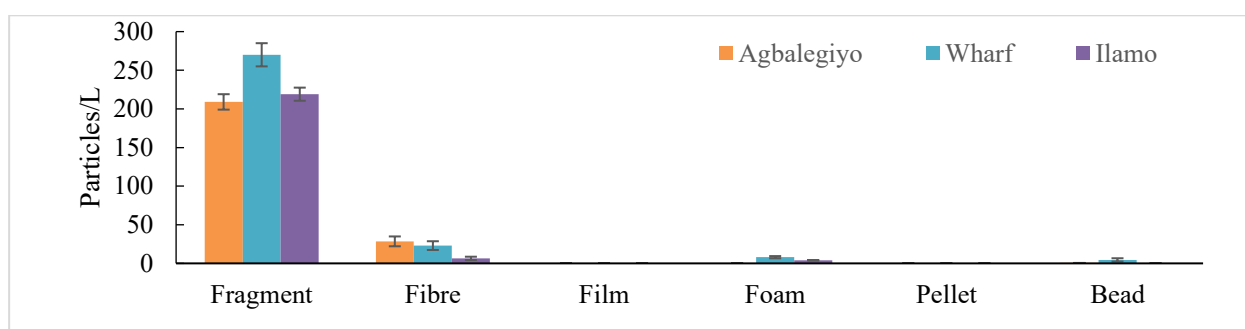


Figure 3: Distribution of microplastics shapes in sediments

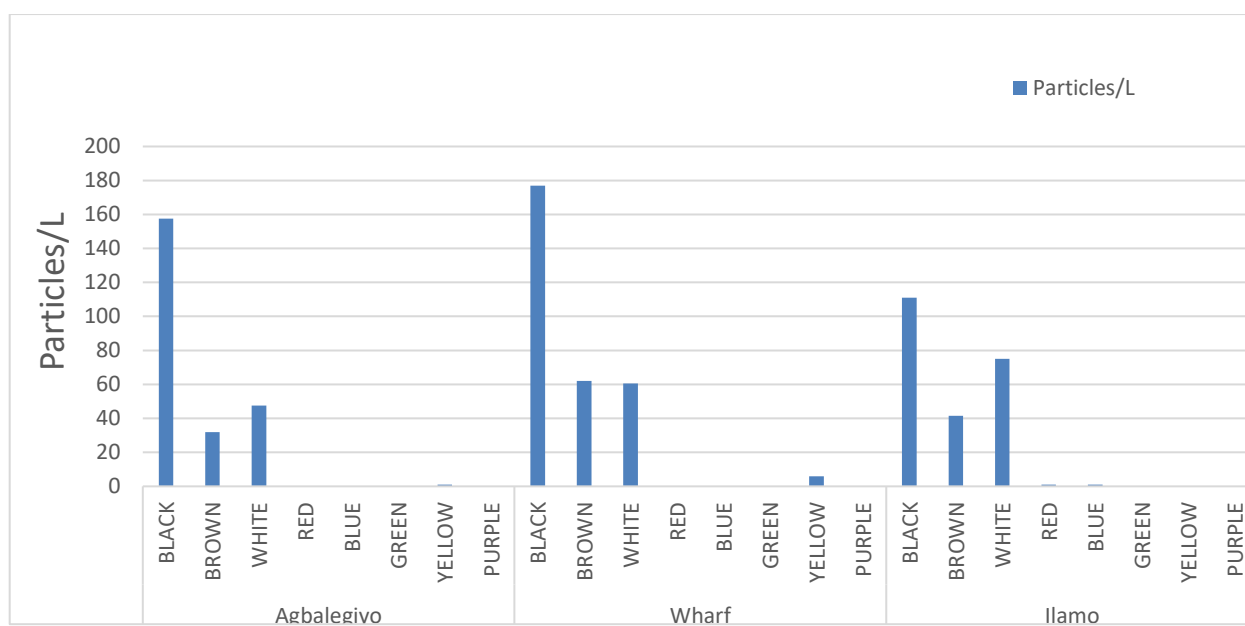


Figure 4: Distribution of microplastics colours in sediments

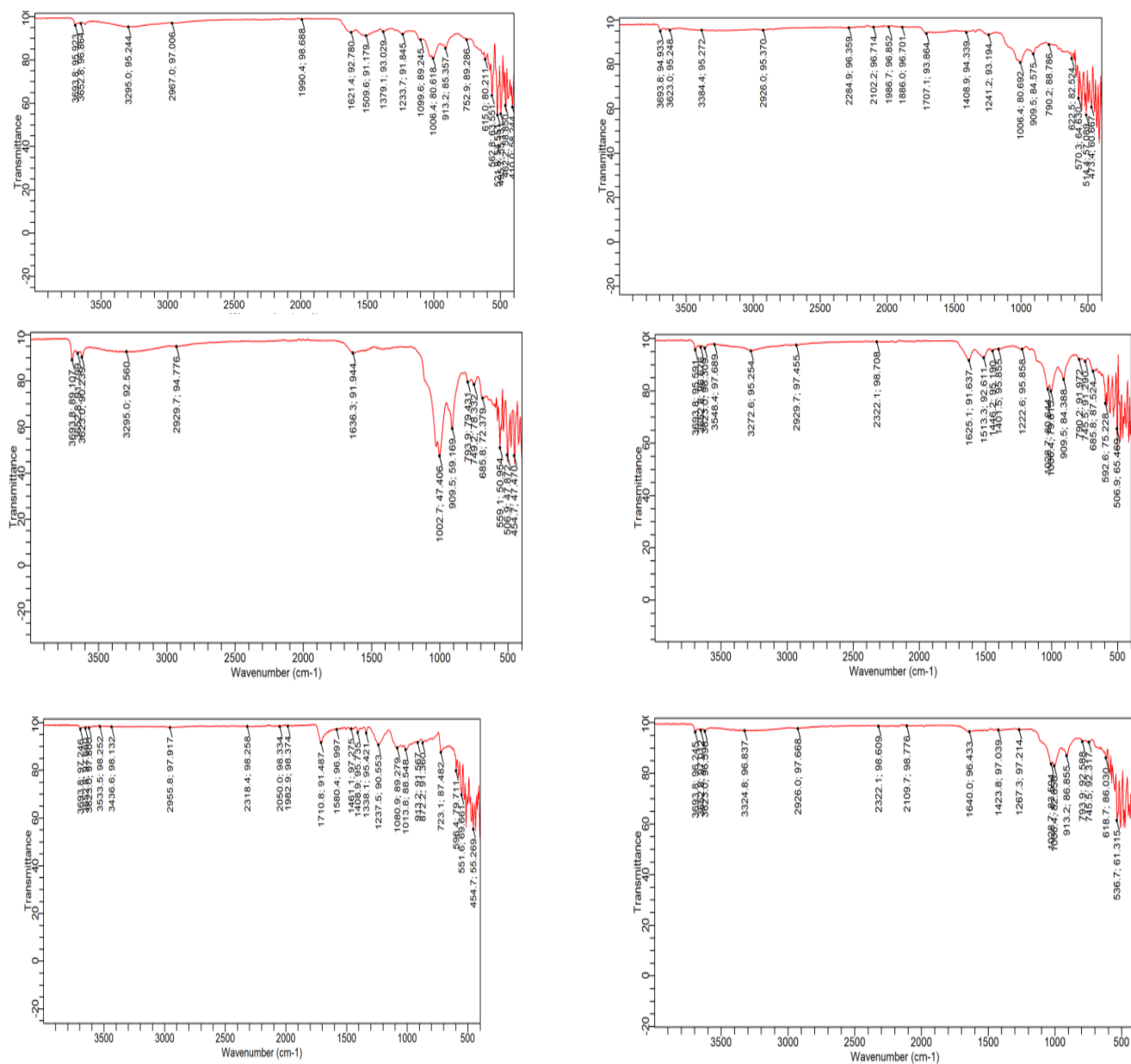


Figure 5: ATR-FTIR spectra for LDPE, PC, PMMA, nylon, PS, PET

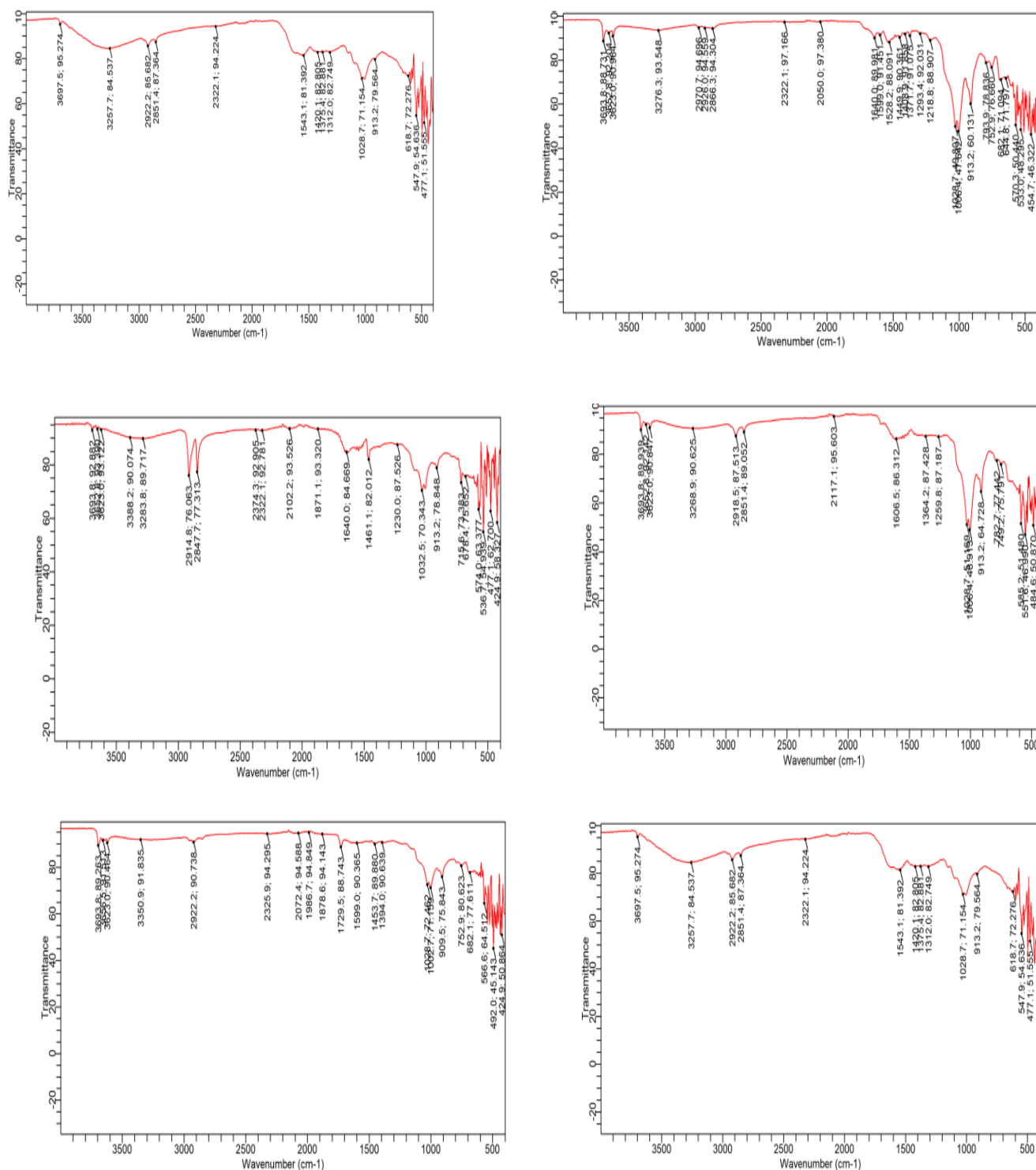


Figure 6: ATR-FTIR spectra for PVC, ABS, PP, HDPE, nitrile, latex

ATR-FTIR spectra identified thirteen polymer types, chiefly polyethylene terephthalate, low-density polyethylene, polyvinyl chloride, and polypropylene as showed in (Figures 5–6).

Polymer diversity peaked in Wharf sediments, coinciding with the highest microplastic loads, whereas Ilomo exhibited the narrowest polymer spectrum. Plate 1 shows selected images of fragments, fibres, films, foams, and beads illustrate the morphological heterogeneity of lagoon

microplastics, with fragments showing both smooth and micrometres in diameter, corroborating stereomicroscope measurements.

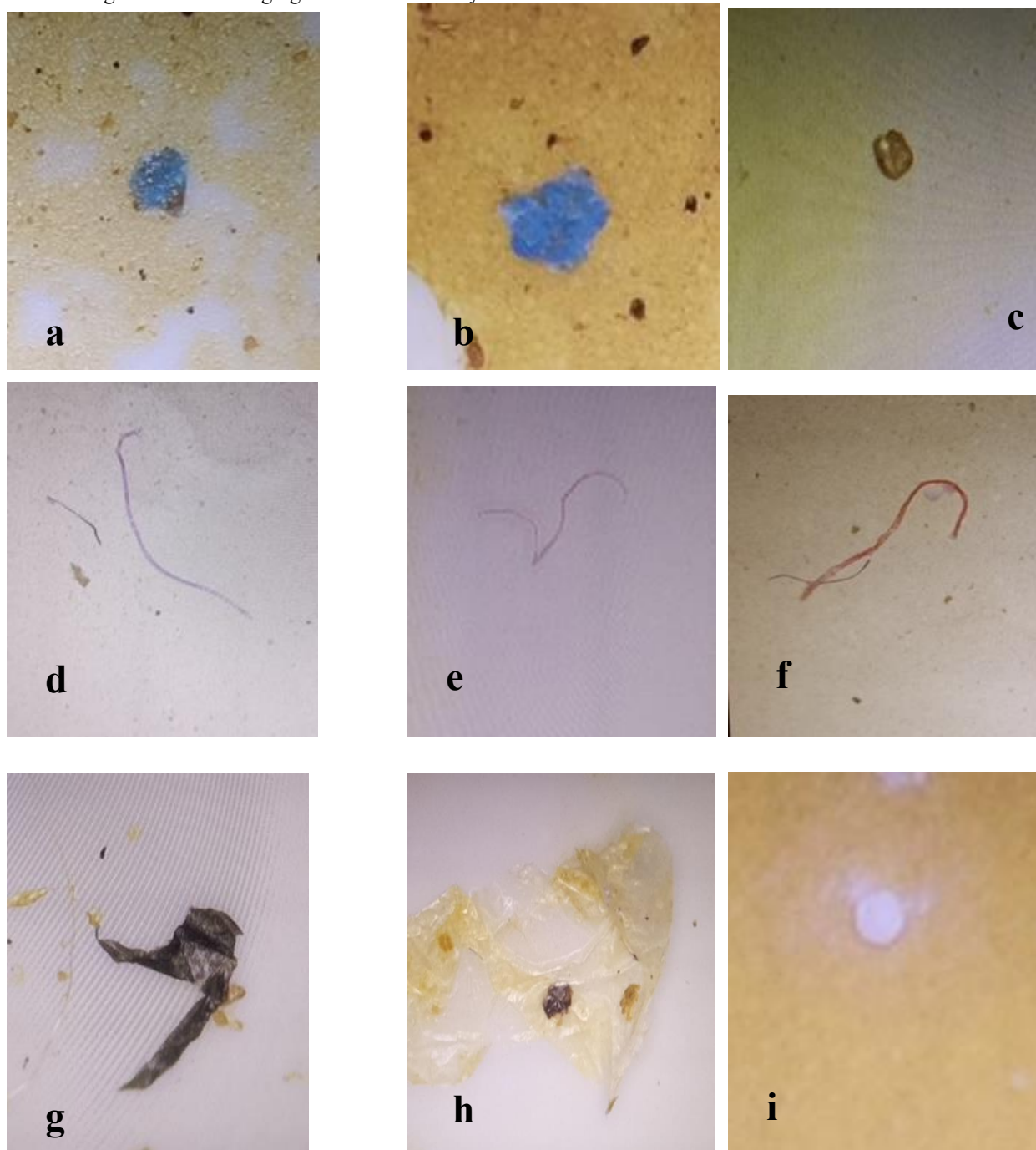


Plate 1: Selected images of microplastics; fragments (a – c), fibres (d – f), films (g – h) and foam (i) from water and sediment samples

Polymer-specific frequencies were highest at 22% followed by polyethylene terephthalate (18%), low-density polyethylene (15%), polyvinyl chloride (13%), polypropylene (8%), polystyrene (5%), with the residual 19% shared among other identified polymers. Heavier polymers displayed greater prevalence in sediment than in water, consistent with density-driven partitioning.

Discussion

In this study, the abundance and morphology of microplastics were examined in the surface water and sediment of the Agbalegiyo, Wharf and Ilamo area of Lekki Lagoon, Nigeria. The overall abundance of microplastics obtained from the sampling points were 435 particles/L, 378 particles/L and 364 particles/L respectively. The microplastic concentration in the surface water in this study exceeds the range earlier published in the Badagry Lagoon but still falls below the highly polluted Osun River making the Lekki Lagoon a hot zone of contamination but not an extreme deviation from other water bodies in Nigeria (Yahaya *et al.*, 2022; Idowu *et al.*, 2024). While for sediment it was 476 particles/kg, 611 particles/L and 459 particles/L for Agbalegiyo, Wharf and Ilamo area of Lekki Lagoon respectively. The most prevalent type of microplastics in the water and sediments was fragments. The prevalence of fragments within water/sediment is explained by the progressive decomposition of macroplastics, especially polyethylene packaging and polypropylene items commonly found in homes, which agree with notes on other tropical systems in which fragmentation mechanisms are catalyzed by heavy ultraviolet radiation and abrasion processes (Thompson *et al.*, 2004; Zhao *et al.*, 2019). The high percentages of black particles in both the water and sediments point to the contribution of vehicular and combustion sources such as tyre wear and soot carried by atmospheric deposition respectively in addition to direct litter contributions (Verlis *et al.*, 2013; Boerger *et al.*, 2010).

The retrieved visible microplastics in sediments were confirmed using ATR-FTIR as polyethylene terephthalate, high density polyethylene, polyvinyl chloride, low density polyethylene, polypropylene, polystyrene, polyurethane, polycarbonate, nylon, latex, nitrile, polymethyl methacrylate, and acrylonitrile butadiene styrene. The identified types of polymers broaden the list of proven synthetic materials in lagoons of Nigeria and unveil a significant role of high-density polymers, like polyvinyl chloride, at risk of sinking, which could explain its relative abundance in sediment samples relative to water samples (Fang *et al.*, 2021; Zhang *et al.*, 2021). Temporal and spatial variations in the diversity of polymers, with the richest set employed in Wharf sediments, reflect different anthropogenic stressors; Wharf is a trans-shipment hub where plastic wrap pallets, paint flakes, and trawler refuse accumulate, and polymers further enrich the diversity of input material (Adeleye *et al.*, 2020; Adekoya, 1995).

Theoretical considerations are related to simulating the fates of the contaminants affecting sedimentation

coefficients, which compel the prediction tool of transport algorithms within low-energy tropical lagoons to update assumptions of toxicants on solid exposures (Liu *et al.*, 2019b; Zhang *et al.*, 2021). The study trades offs are that the methodology used is visual, which might underestimate the prevalence of nano-plastic, and that it is just one temporal snapshot, which does not allow seasonal comparisons; however, high levels of quality control, using procedural blanks, and acid-washing glassware ensures that the study has minimal false positive results increasing its internal validity (Shruti and Kutralam-Muniasamy, 2019; Lassen *et al.*, 2015). Politically, the current Extended Producer Responsibility regime in Nigeria lacks forcefulness; adding compulsory reporting of production amounts of plastics, the baseline thresholds of recycled composition, and taxes imposed on biodegradable options, or the opposite can significantly achieve macro-plastic discharge into the lagoon catchment thus breaking the continuum of fragmentation observed in this study (Adeleye *et al.*, 2020; Adekoya, 1995). Community-based behavioural change interventions, such as plastic literacy campaigns and paying people to collect waste so as to reduce its abundance, have also been shown effective in similar coastal regions and could act as a force multiplier of institutional action, resulting in a multi-actor coalition that can bend the pollution curve. Scientifically, the current data set will ensure base levels of concentration to which the effectiveness of the future interventions can be determined; repeat experiments using the same protocol will enable tracking possible trends, and the comprehensive library of polymers obtained in this study can potentially be incorporated into the regional databases of spectral searchers, which will allow faster identification of subsequent samples and promote cross-laboratory comparability (Thompson *et al.*, 2004; Zhang *et al.*, 2021). Lastly, geographic information system mapping of microplastic areas of concentration combined with hydrodynamic modelling will increase spatial prioritisation accuracy of targeted clean-up operation and enable adaptive governance that can adapt according to evidence and stakeholder input (Akinhanmi *et al.*, 2023; Idowu *et al.*, 2024).

Conclusion

This study forms a strong empirical background on supporting the prevalence of microplastic in the Lekki Lagoon ecosystem, surface water and sediments. Microplastics were detected in all the water and sediment observed demonstrating their widespread distribution within the lagoon environment. Sediment contained the highest concentration, affirming its role as a major sink for microplastic particles. For the water sample observed the highest abundance of microplastics were found in Agbalegiyo while the least was found in Ilamo, why for the sediment the highest no of microplastics were recorded in Wharf why the least was recorded at Ilam. All matrices were composed of fragmented particles as most abundance, also ATR-FTIR analysis showed a wide spectrum of plastic diversity (13 synthetic polymer types in sediment MPs) such as polyethylene terephthalate, polyvinyl chloride, polypropylene etc.

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